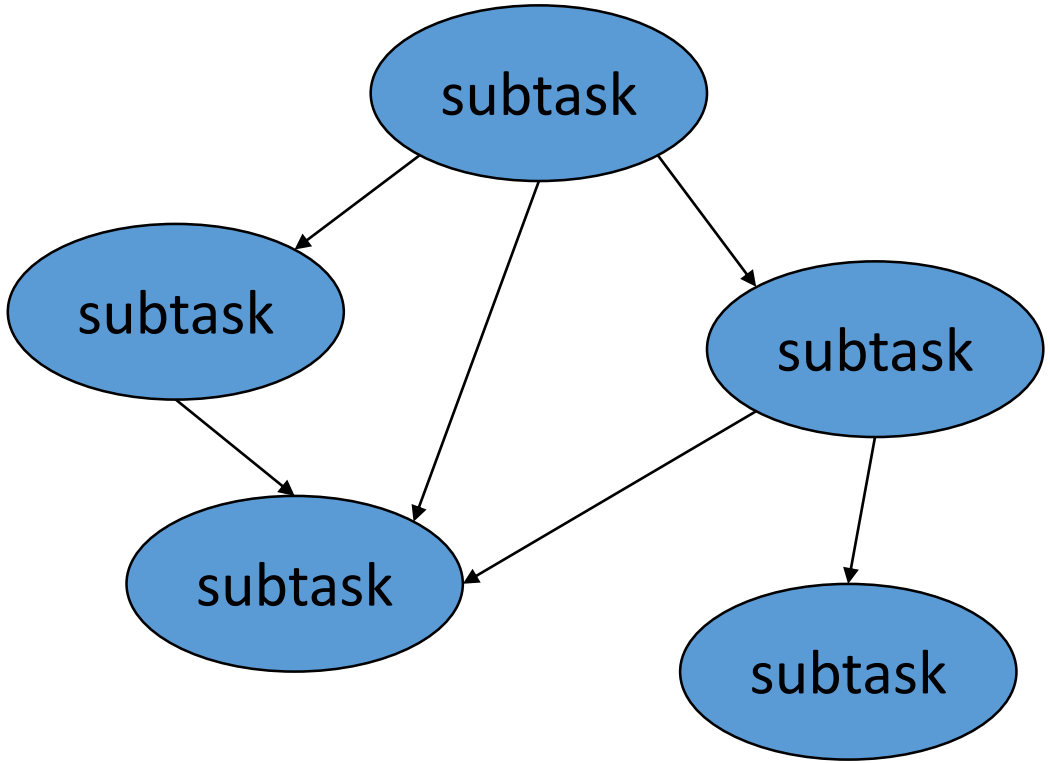
Trading Cores for Memory Bandwidth in Real-time Systems

Ahmed Alhammad and Rodolfo Pellizzoni

Outline

- Introduction
- Problem Description
- Our Solution
- Conclusion

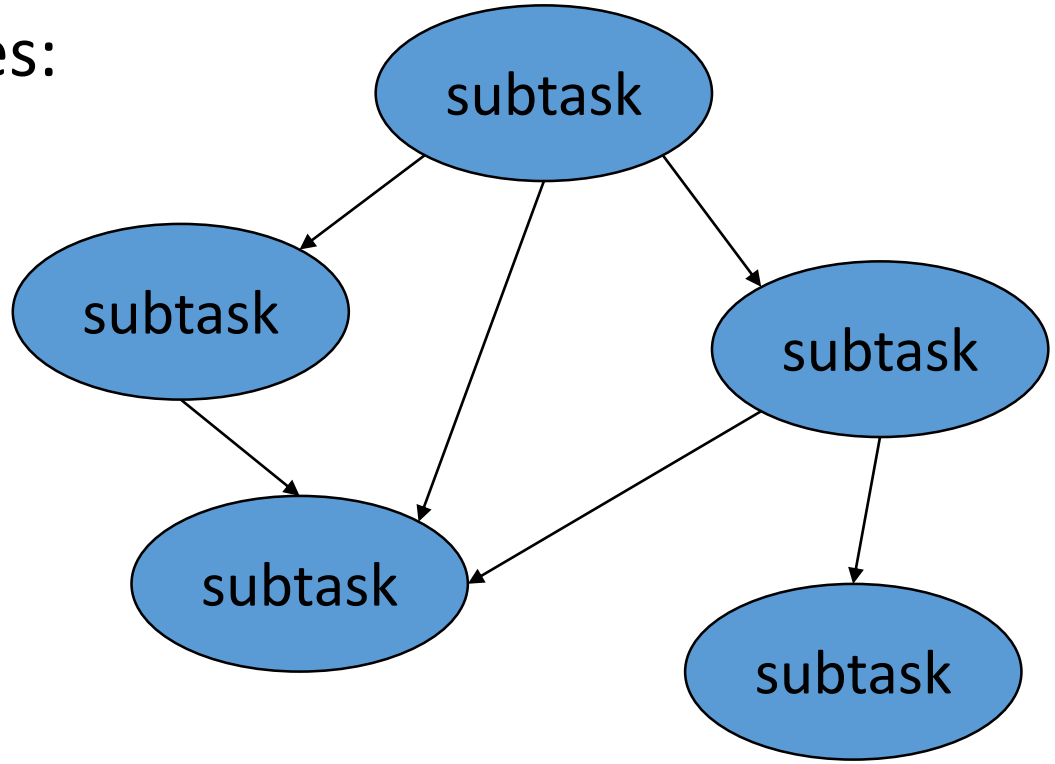
Parallel Tasks



DAG Model

Parallel Tasks

- Two notable scheduling schemes:
    1. Global
    2. Federated



DAG Model

Federated Scheduling

- High utilization tasks ($u_i \geq 1$) are assigned dedicated cores.
- Low utilization tasks ($u_i < 1$) are scheduled as multiprocessor scheduling of sequential tasks.

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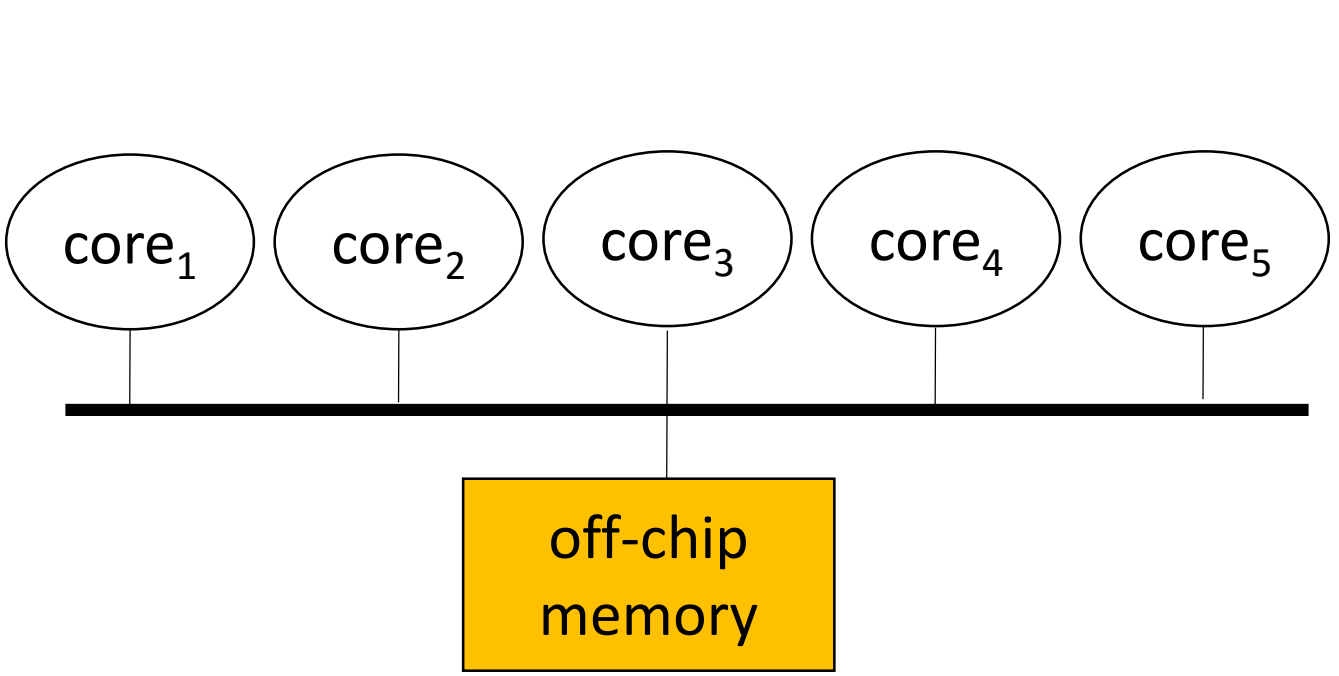
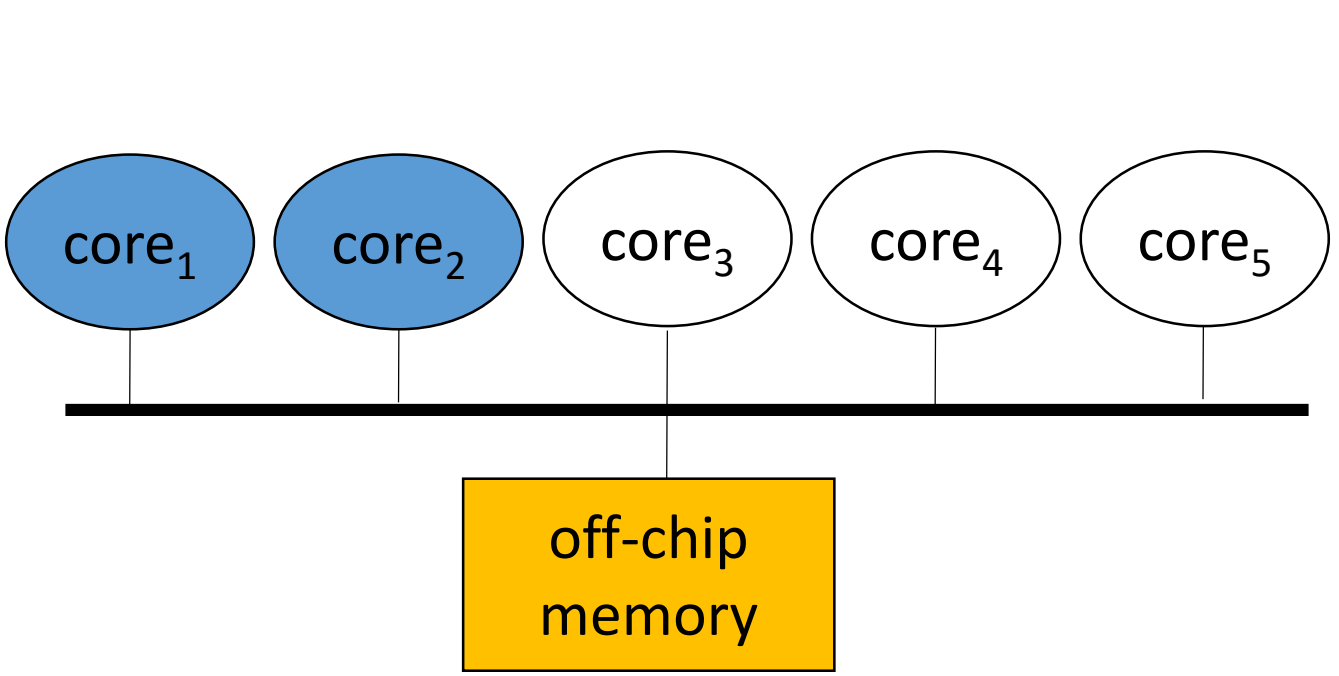

core1
core2
core3
core4
core5
off-chip memory


task1
task2
task3

The Problem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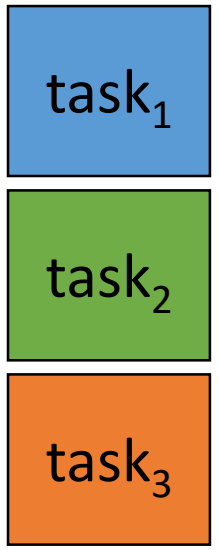
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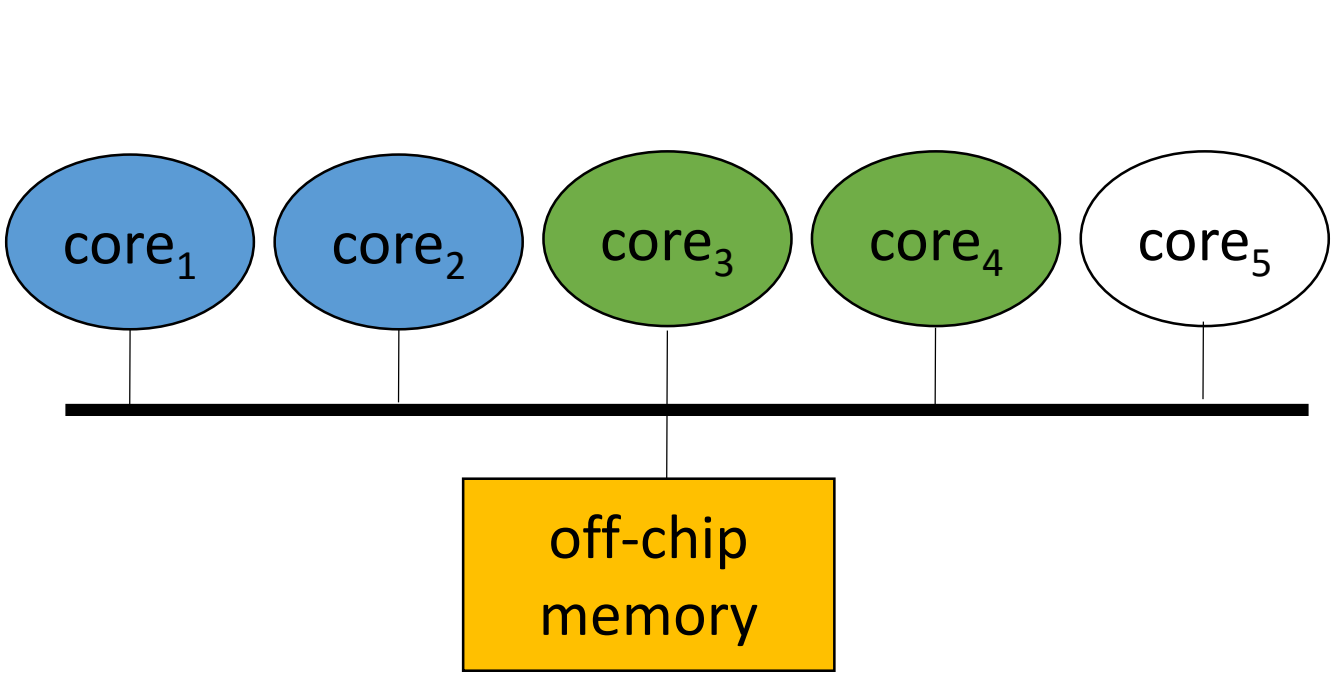
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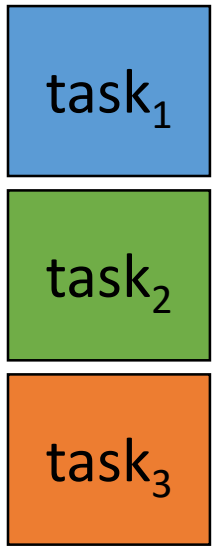
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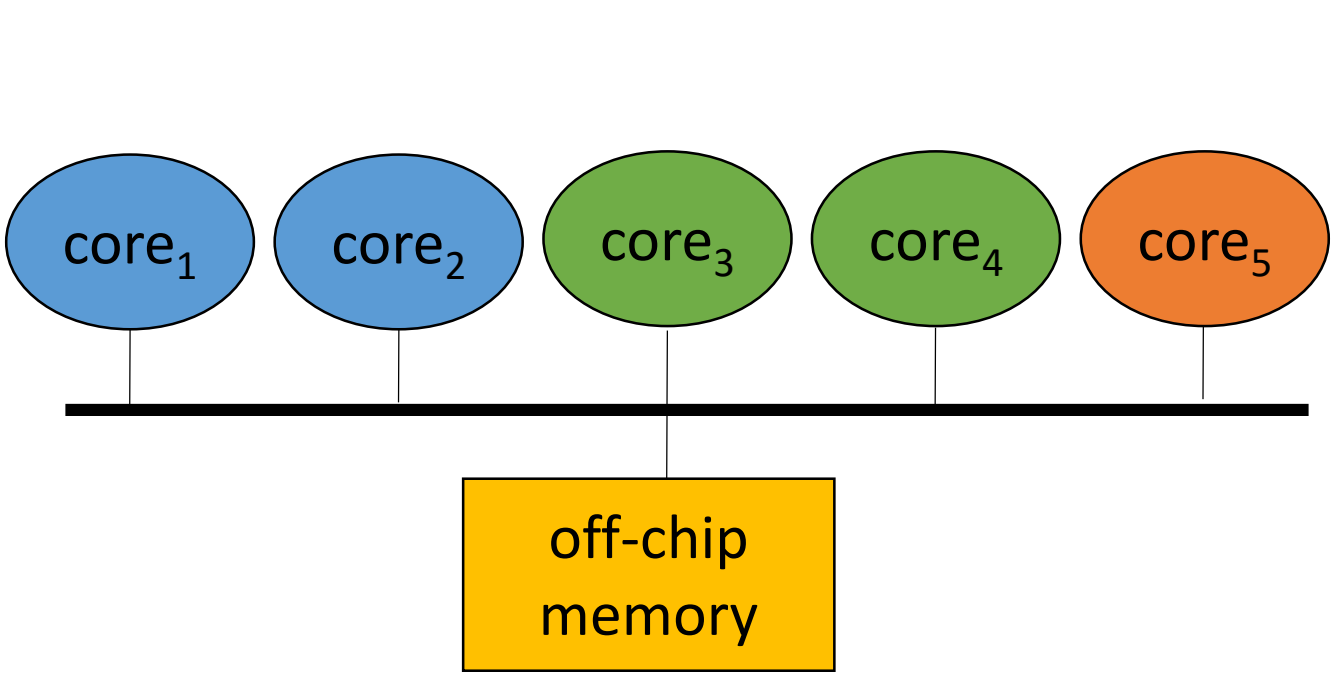
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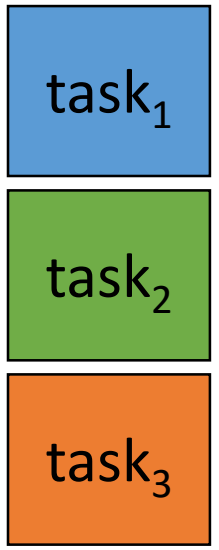
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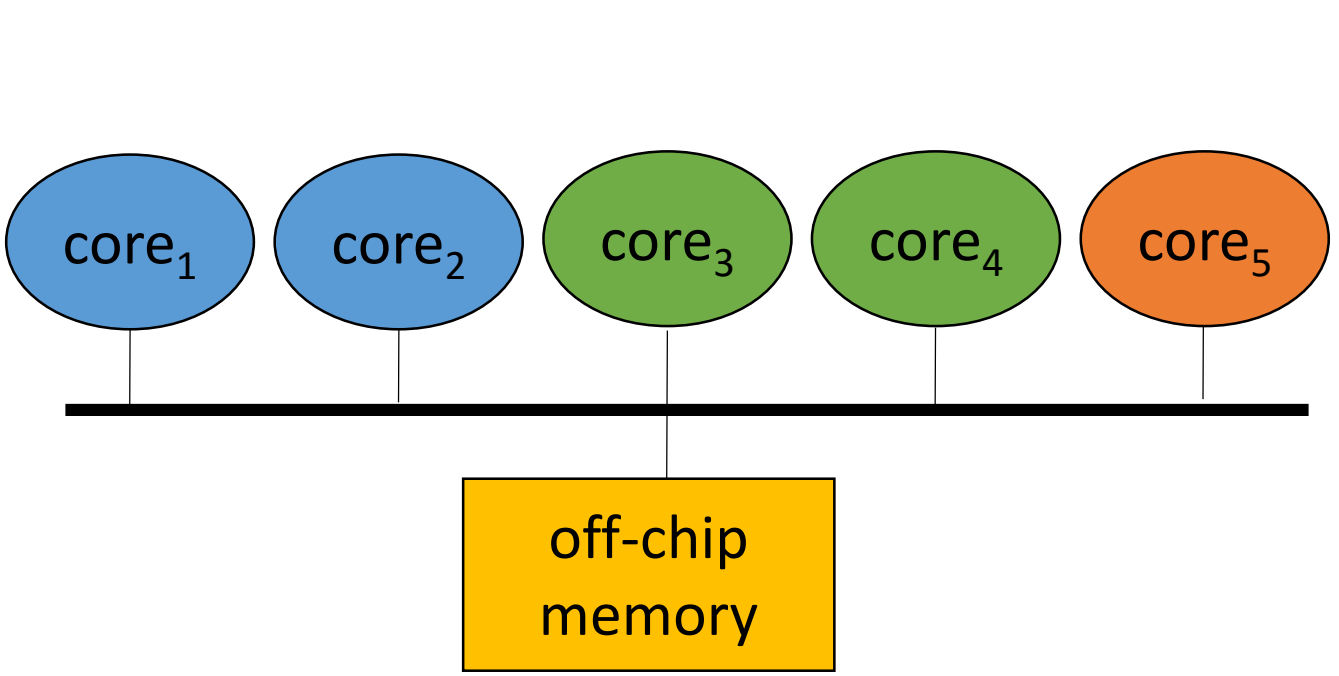

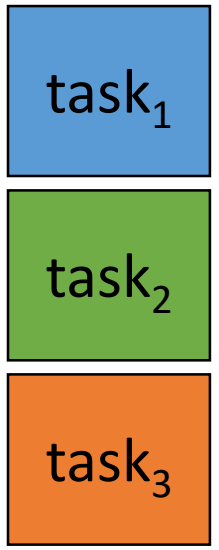

- Tasks interfere through shared main memory

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  2. Round-robin Arbitration
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  4. Three Algorithms
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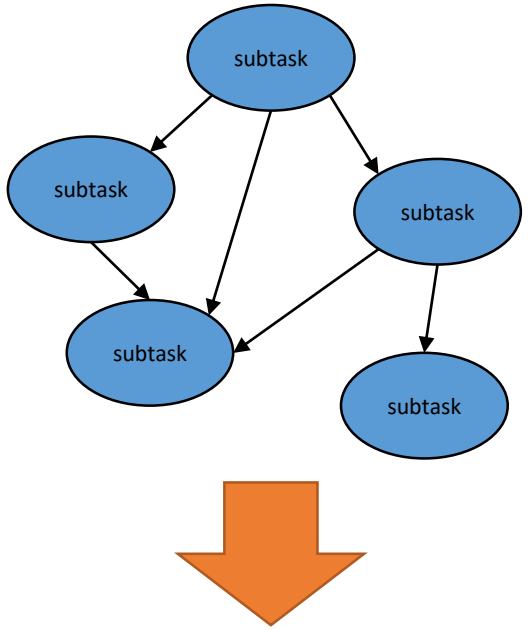
Makespan Bound (greedy scheduling)



m_i number of cores

q_i bandwidth fraction

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- Each DAG task is characterized by:
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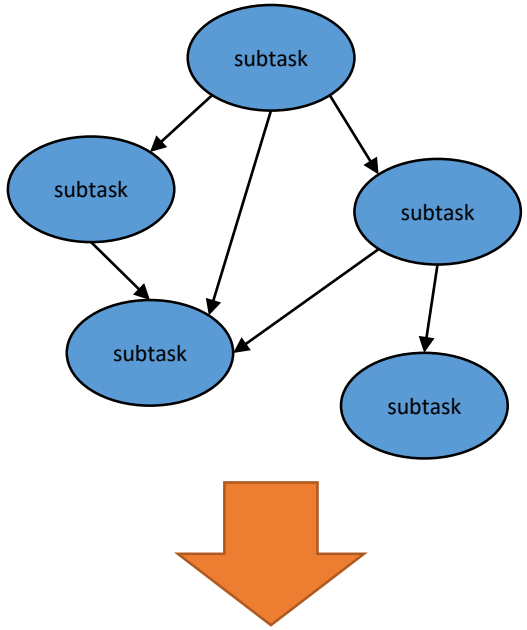

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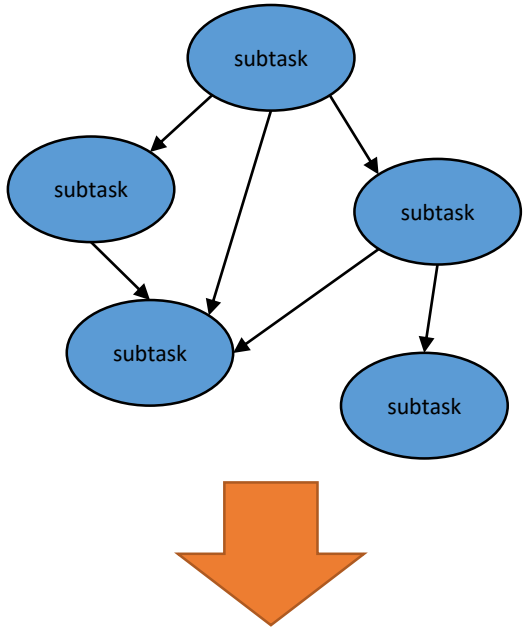

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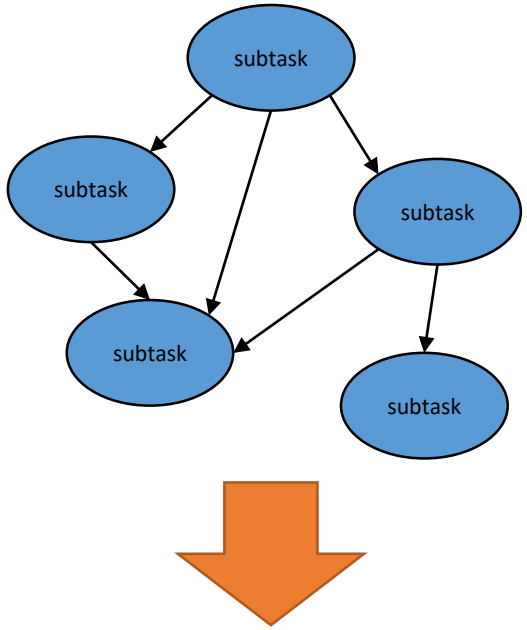
memory time

computation time



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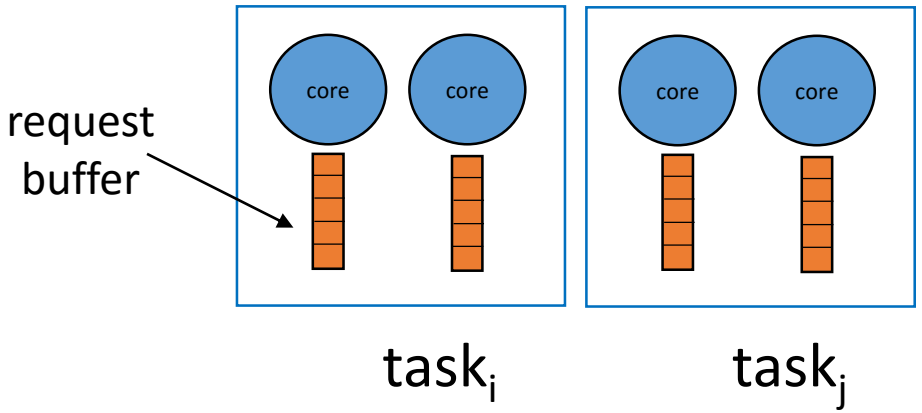

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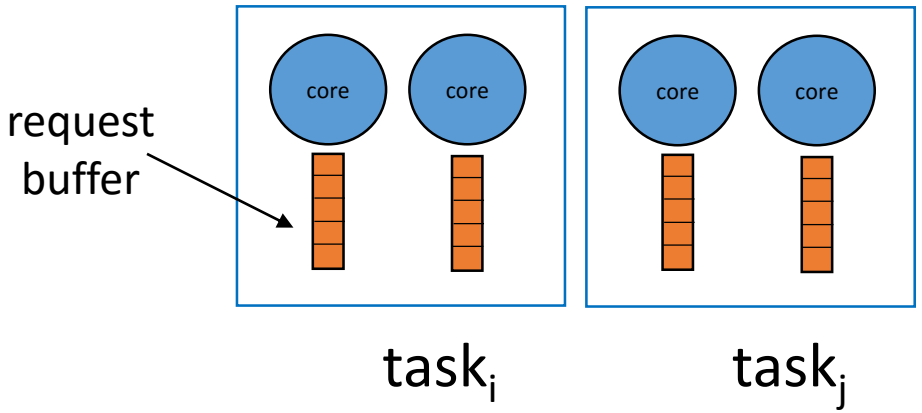

- $C_i^m + C_i^m \times (\sum_{j \neq i} m_j)$

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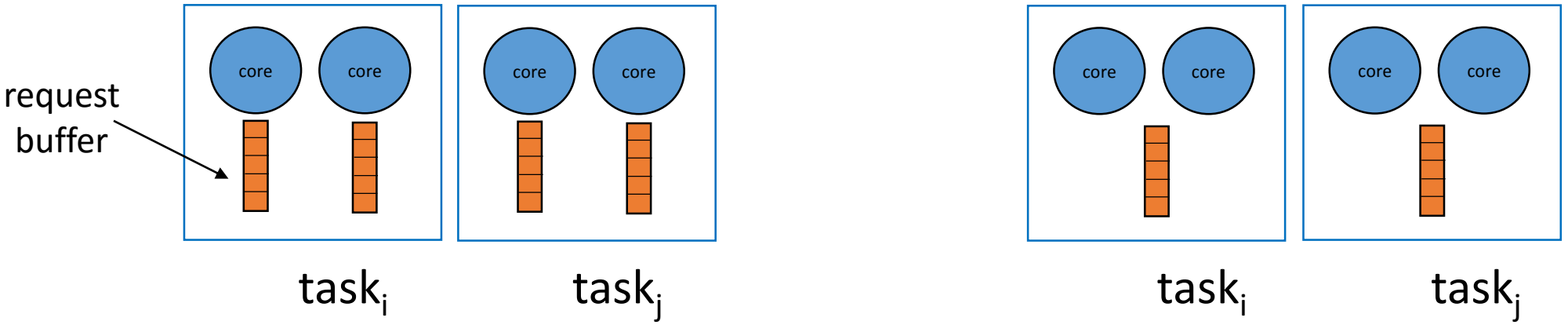

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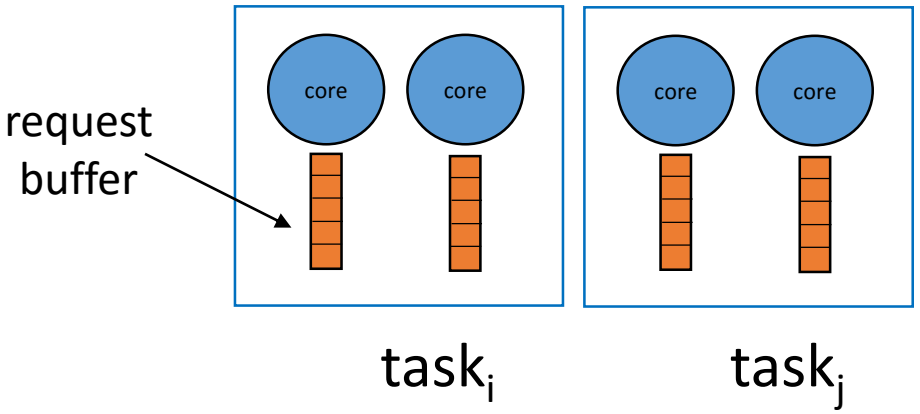

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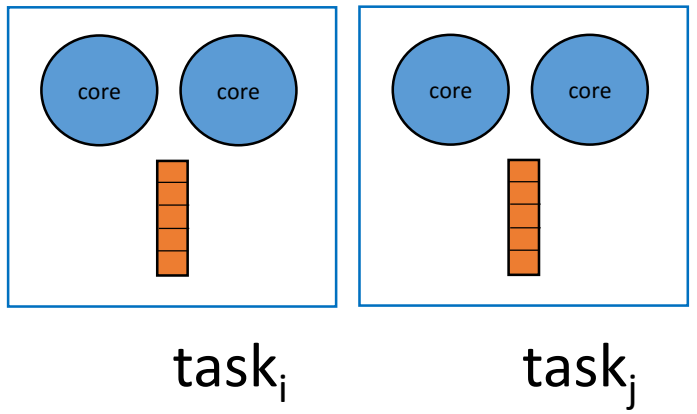

- $C_i^m + C_i^m \times (n-1)$

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- Tasks have different demand regarding memory
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- The idea of trading cores for memory bandwidth

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Assignment Algorithm

- Assign each task q_i and m_i such that

$$\sum_{i=1}^{n} q_i \leq 1 \text{ and } \sum_{i=1}^{n} m_i \leq m$$

- We propose three algorithms:
  - (1) Optimal algorithm with $q_i \in \mathbb{R}$
  - (2) Harmonic RR with $q_i = 1/2^j$
  - (3) Software-based regulation

Optimal-Assign Algorithm ($q_i \in \mathbb{R}$)

- $C_i = \frac{C_i^m}{q_i} + \frac{C_i^e - L_i}{m_i} + L_i \leq D_i$

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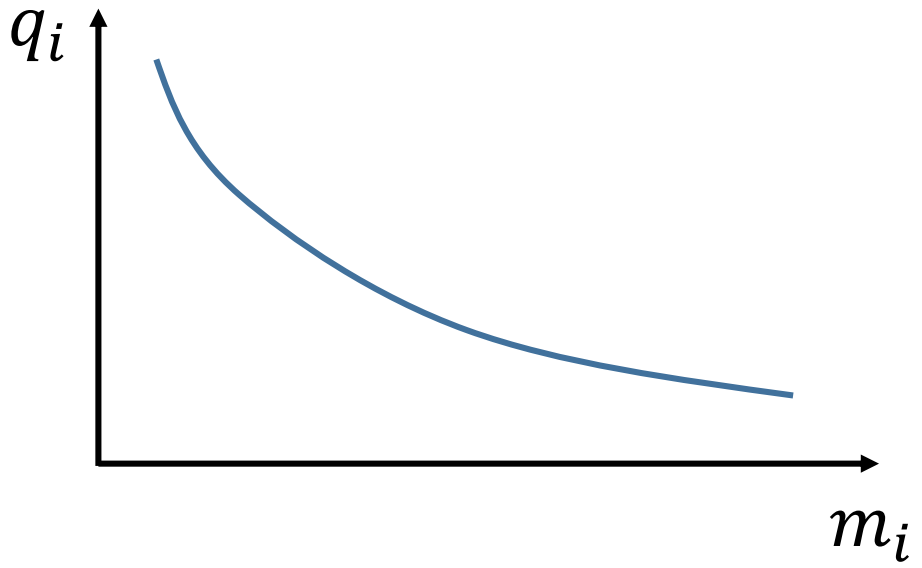

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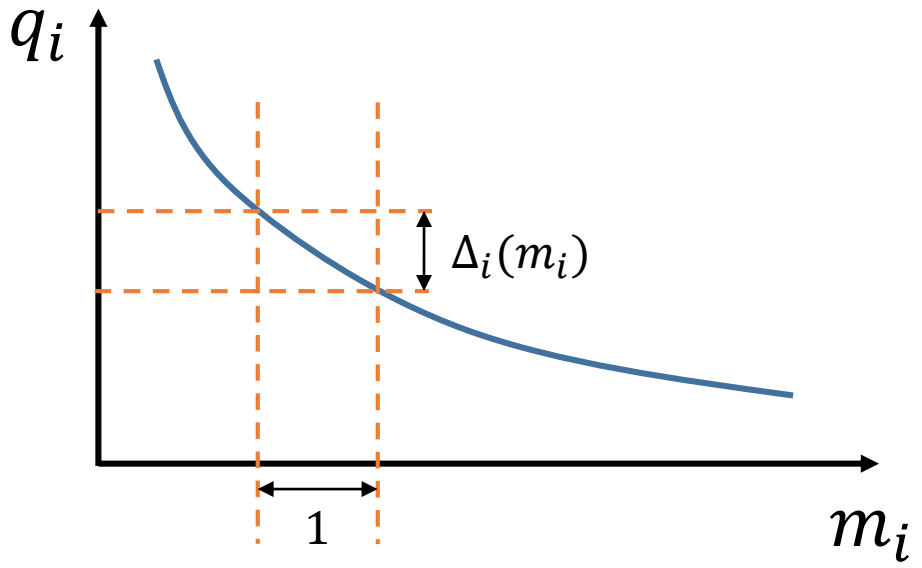

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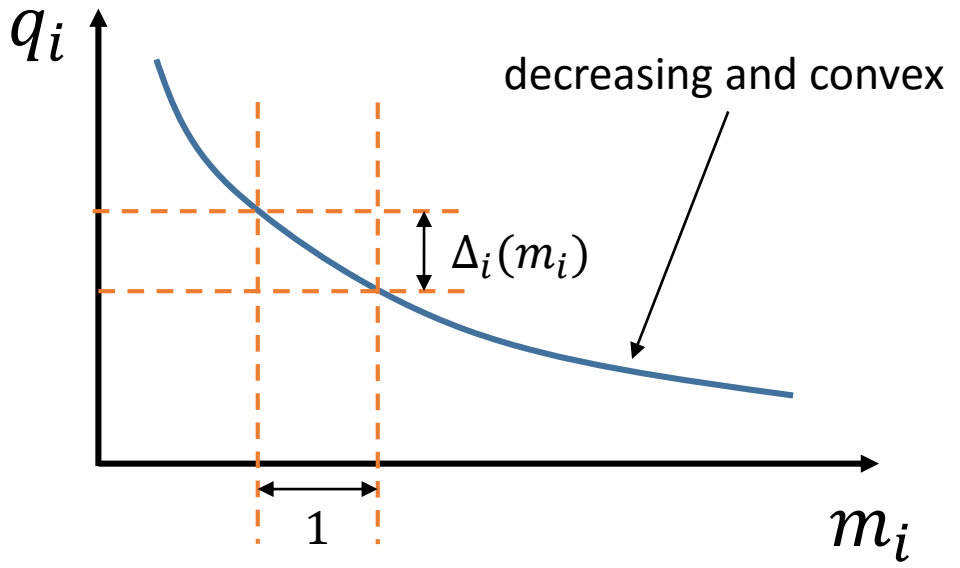

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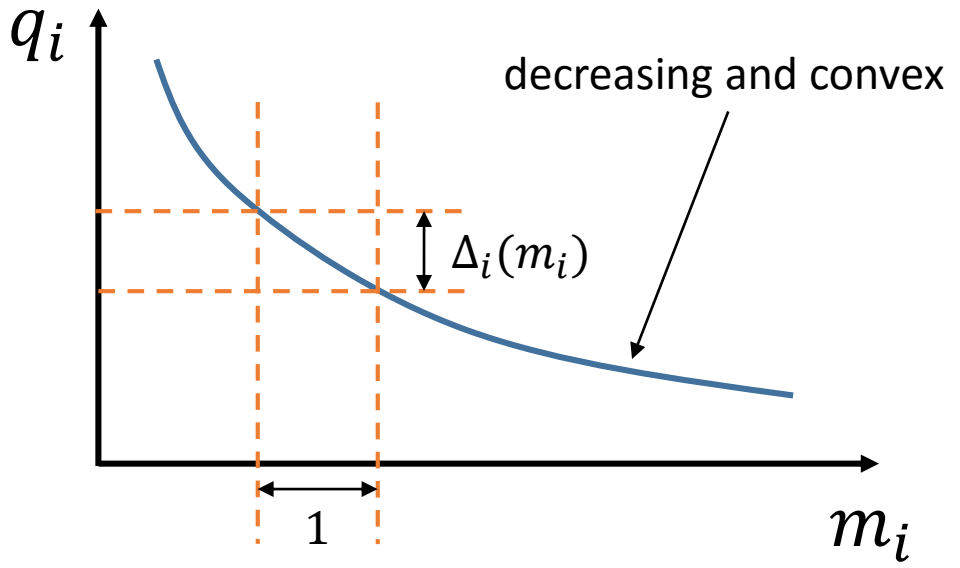
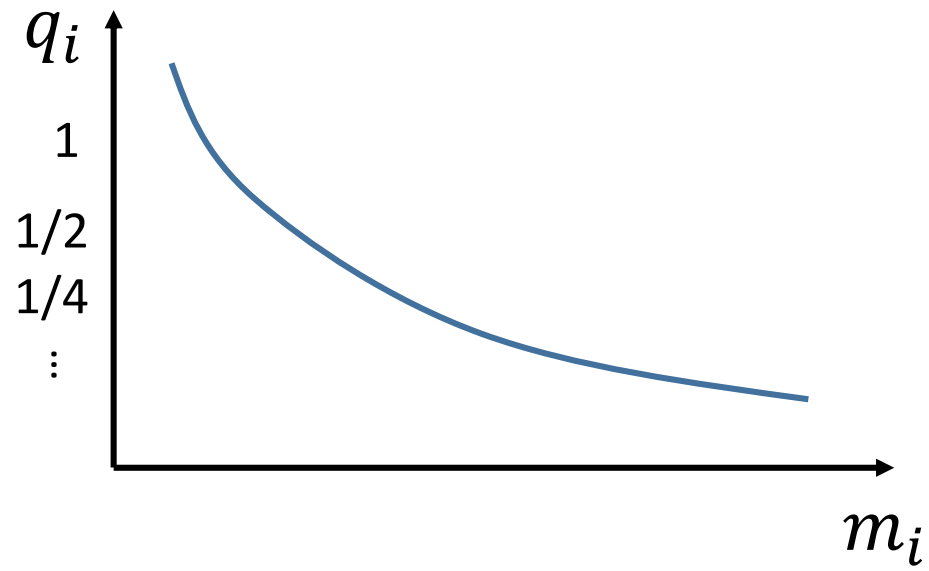
- $\Delta_i(m_i) = q_i(m_i) - q_i(m_i + 1)$
- $\Delta_i(m_i) > 0$ and $\Delta_i(m_i) > \Delta_i(m_i + 1)$



Harmonic RR ($q_i \in \{1/2^j\}$)



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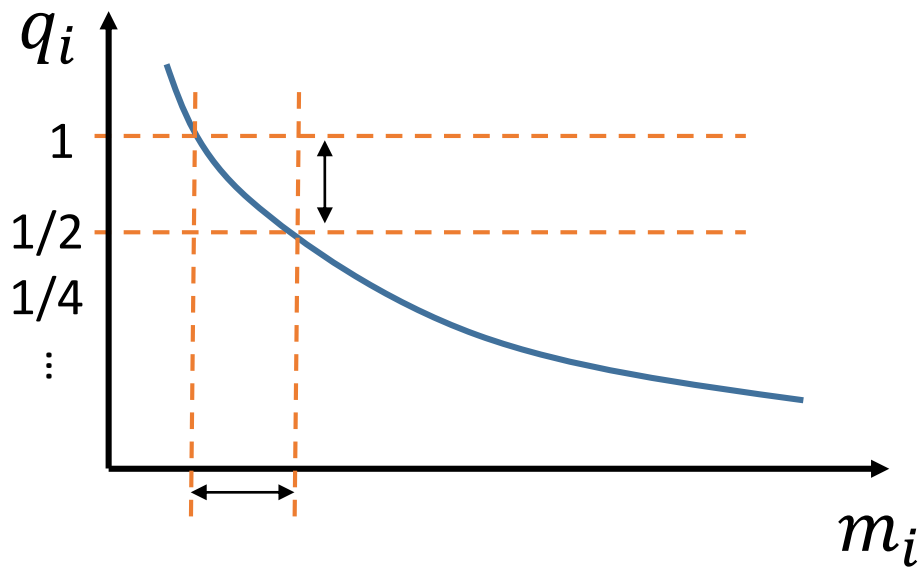

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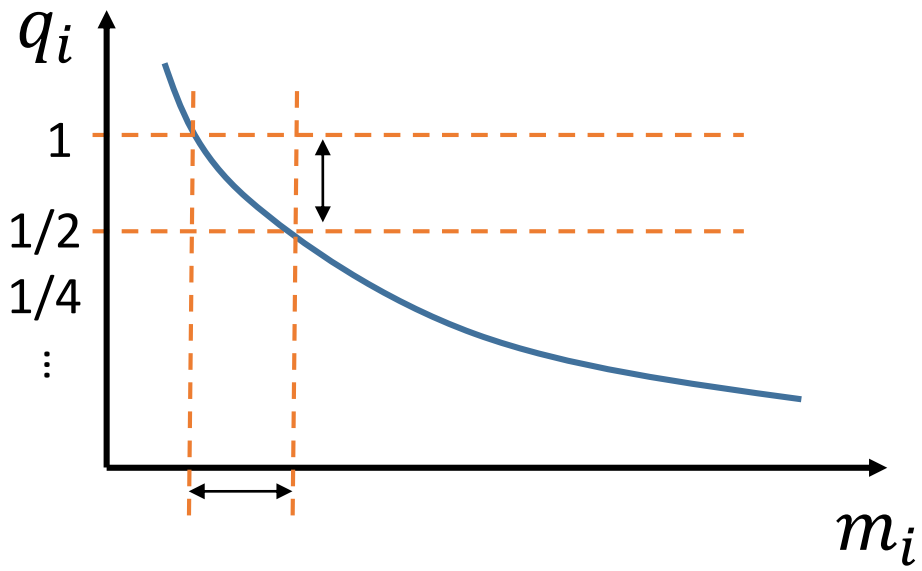
- We design the algorithm to continue until achieving 100% bandwidth utilization.



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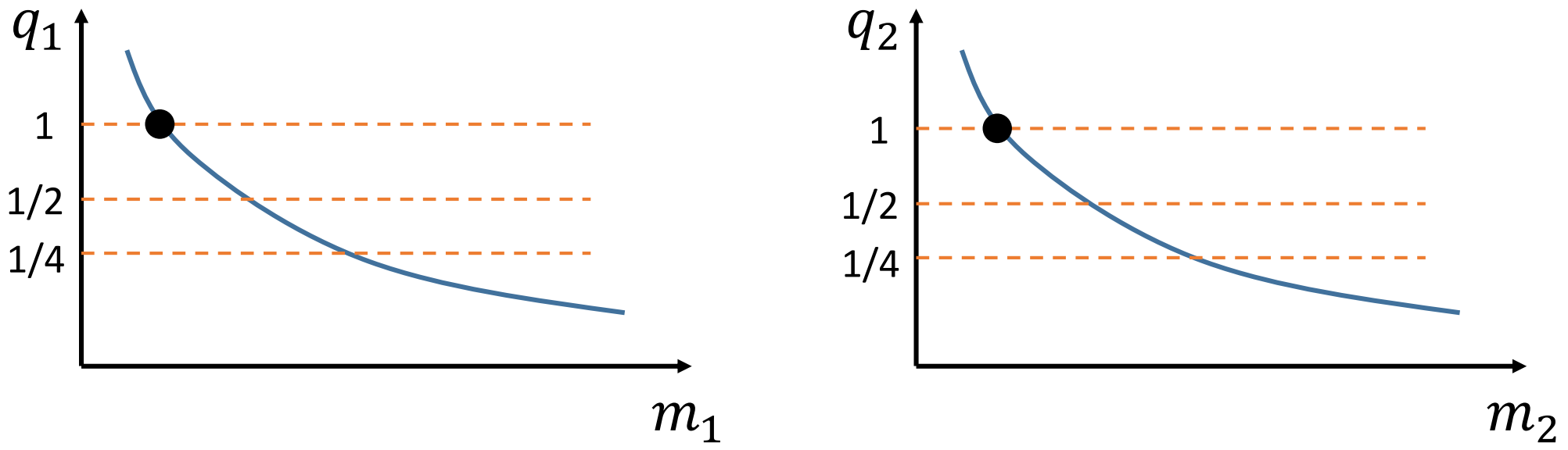
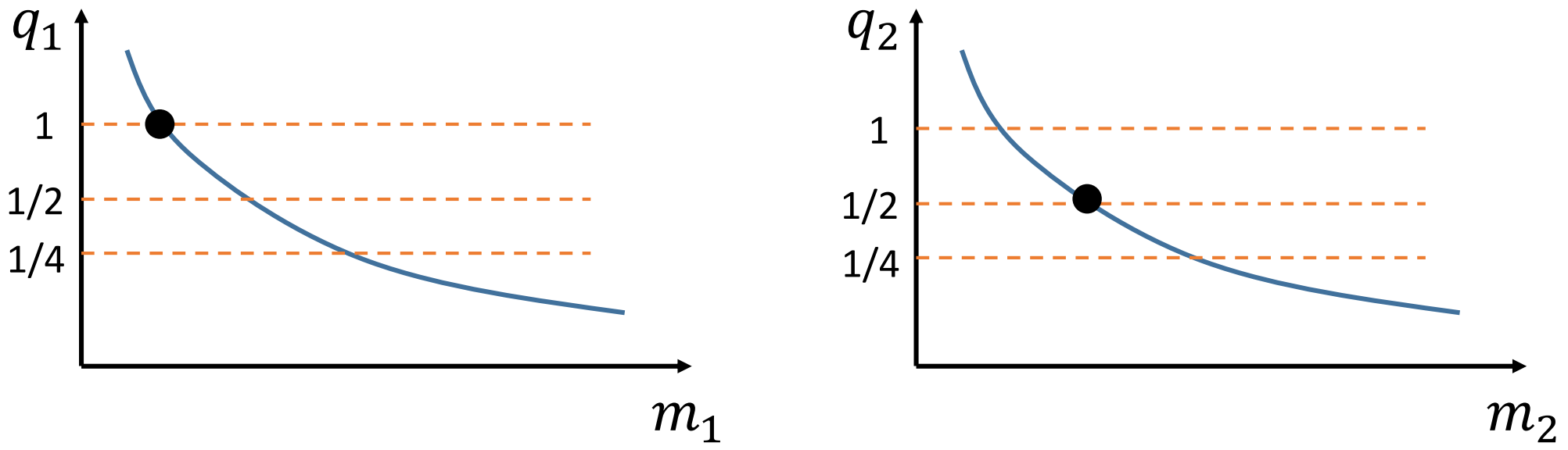


$$q_1 + q_2 = 2$$

Example



$$q_1 + q_2 = 1.5$$

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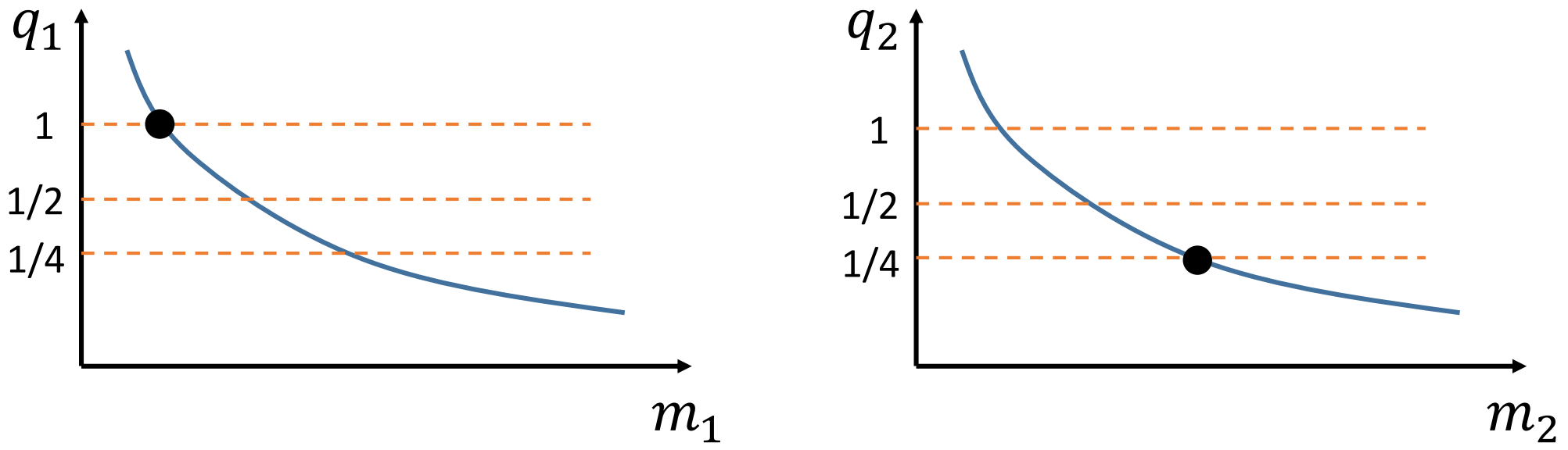

$$q_1 + q_2 = 1.25$$

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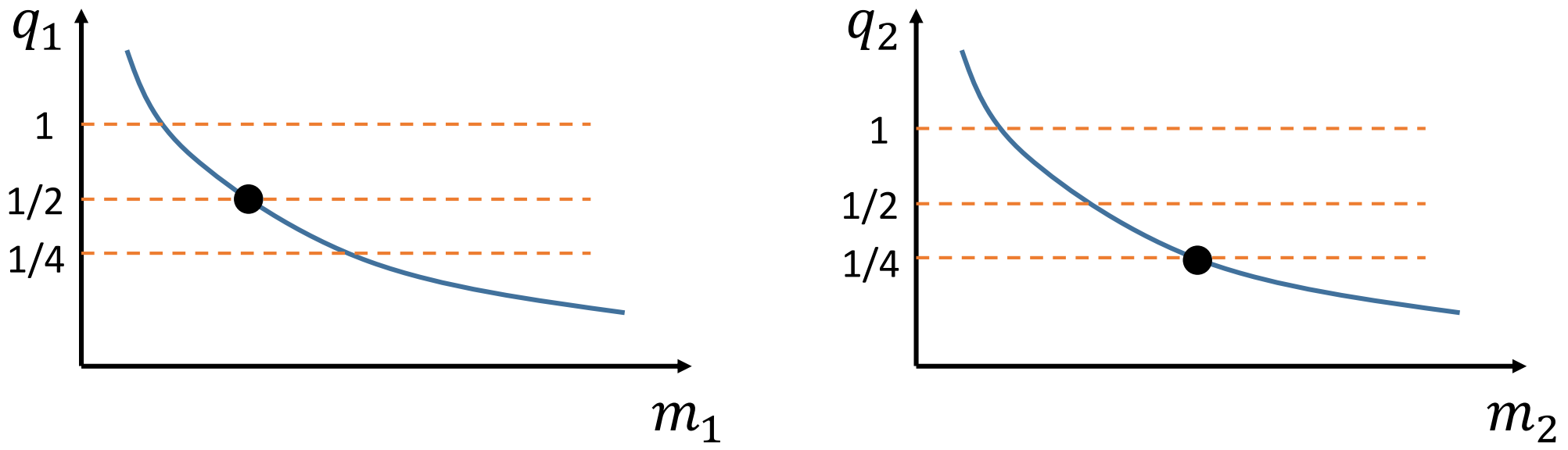

$$q_1 + q_2 = 0.75$$

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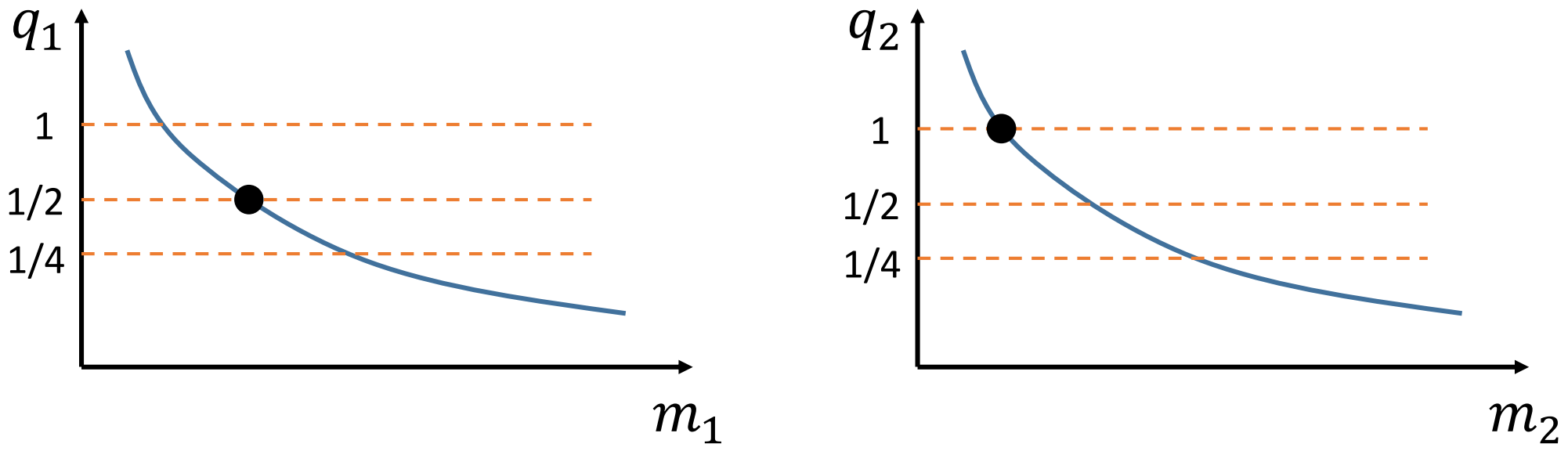

$$q_1 + q_2 = 1.5$$

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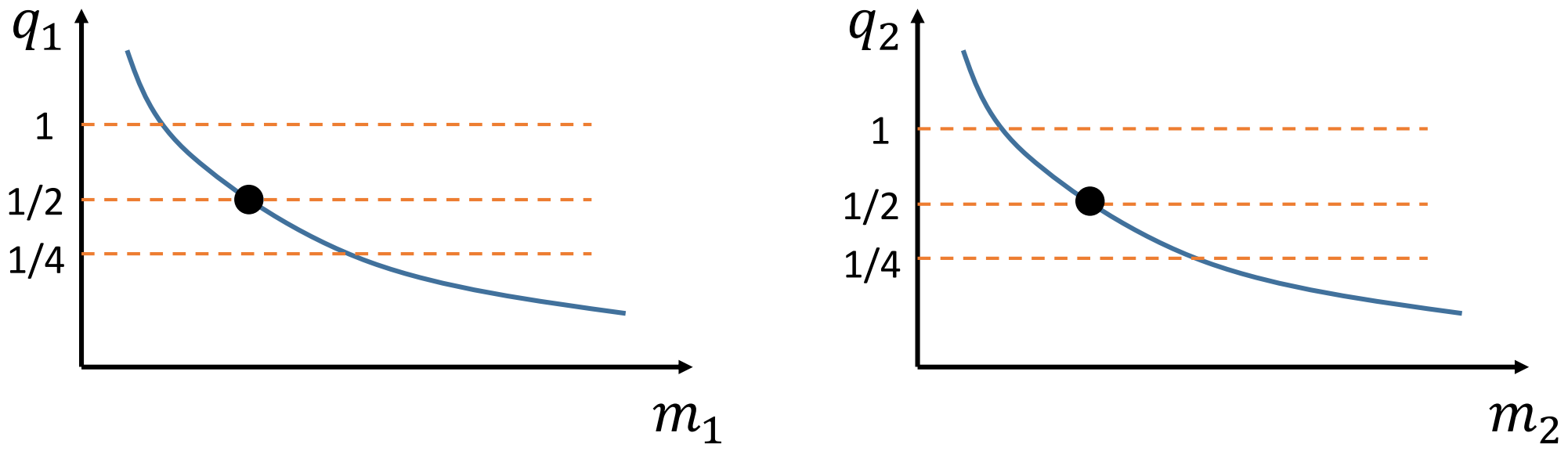

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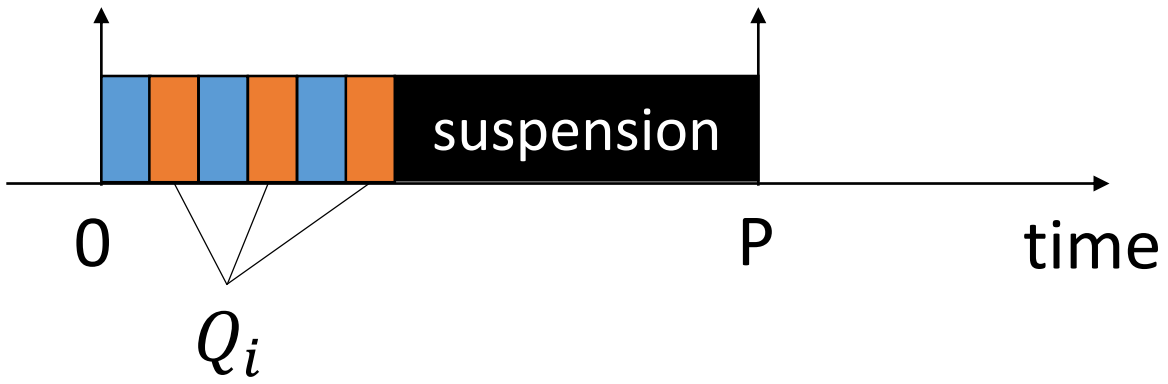

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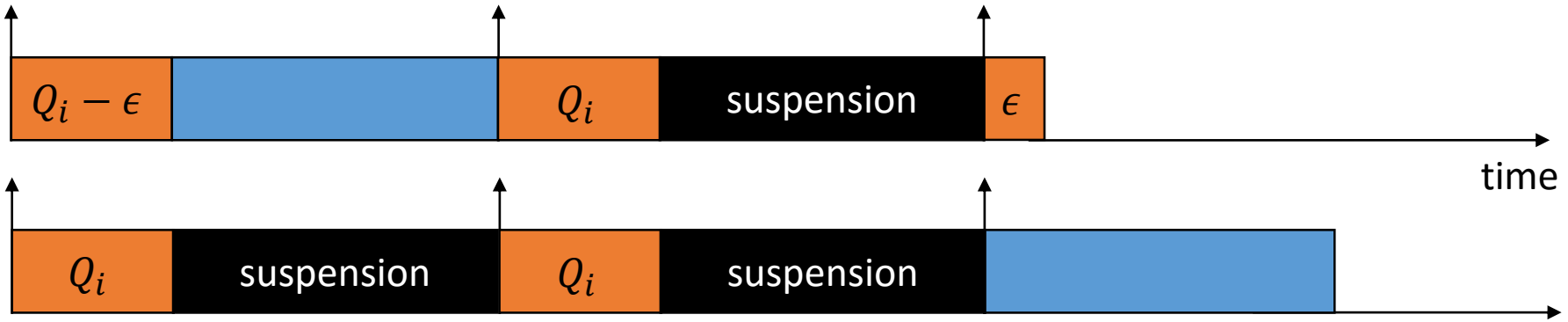

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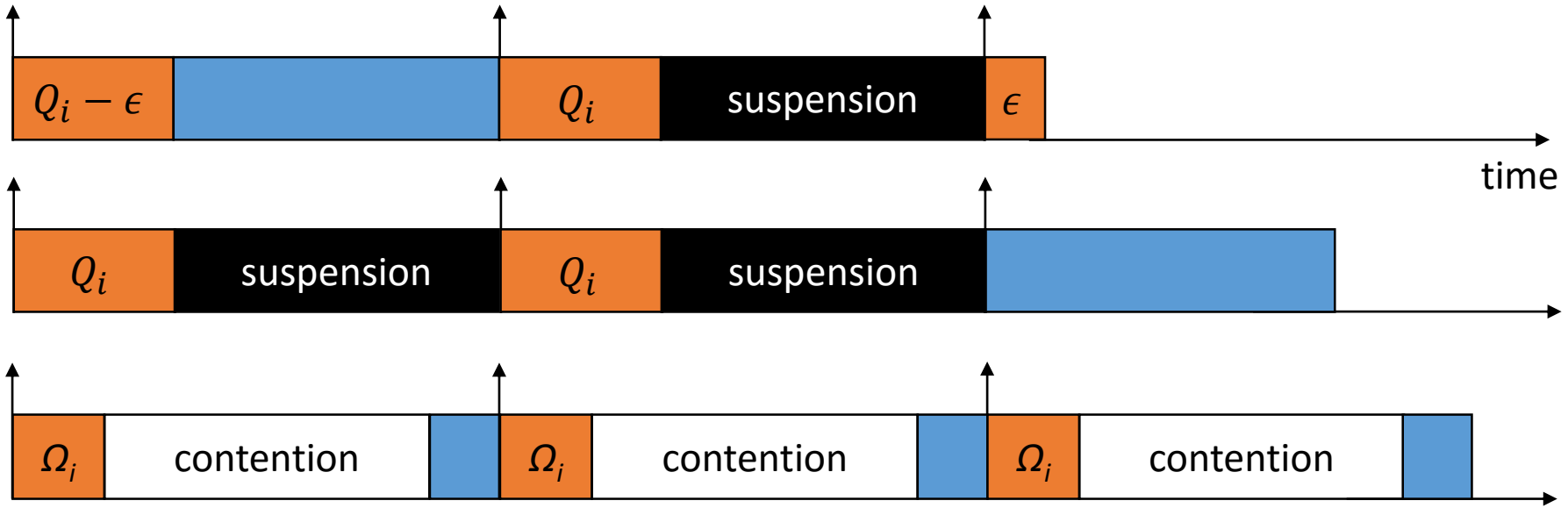

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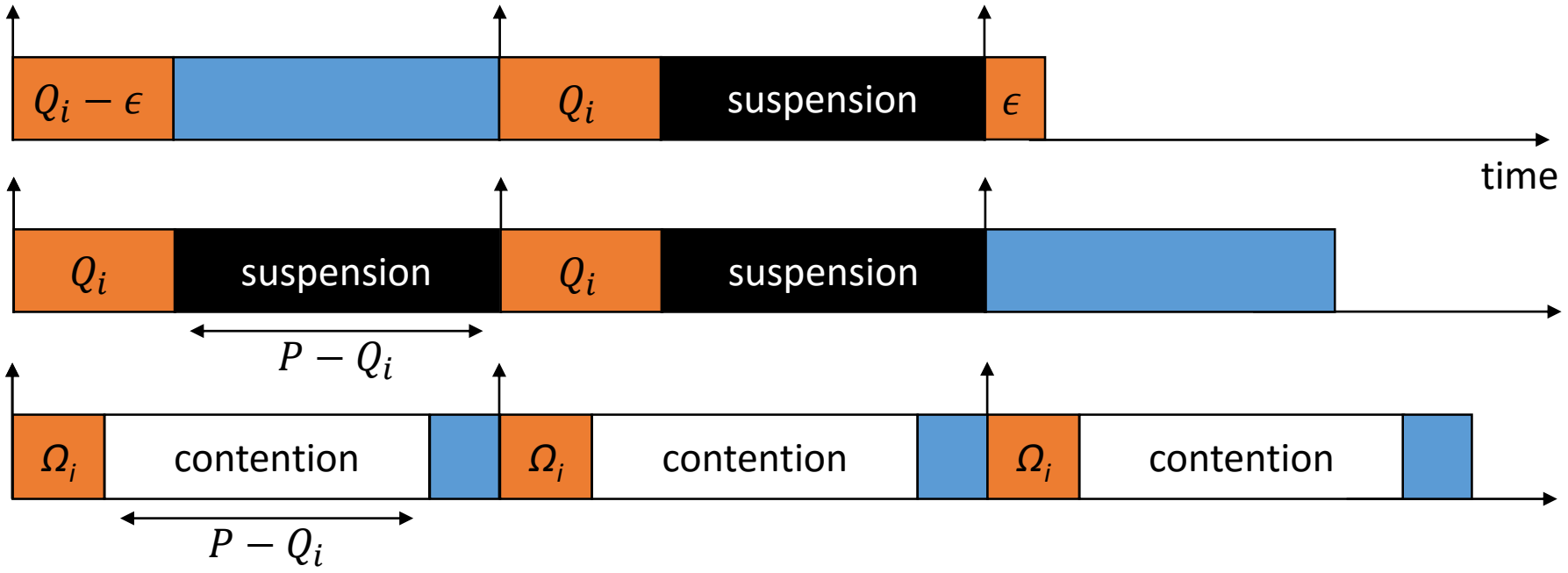

How to Compute Memory Time?

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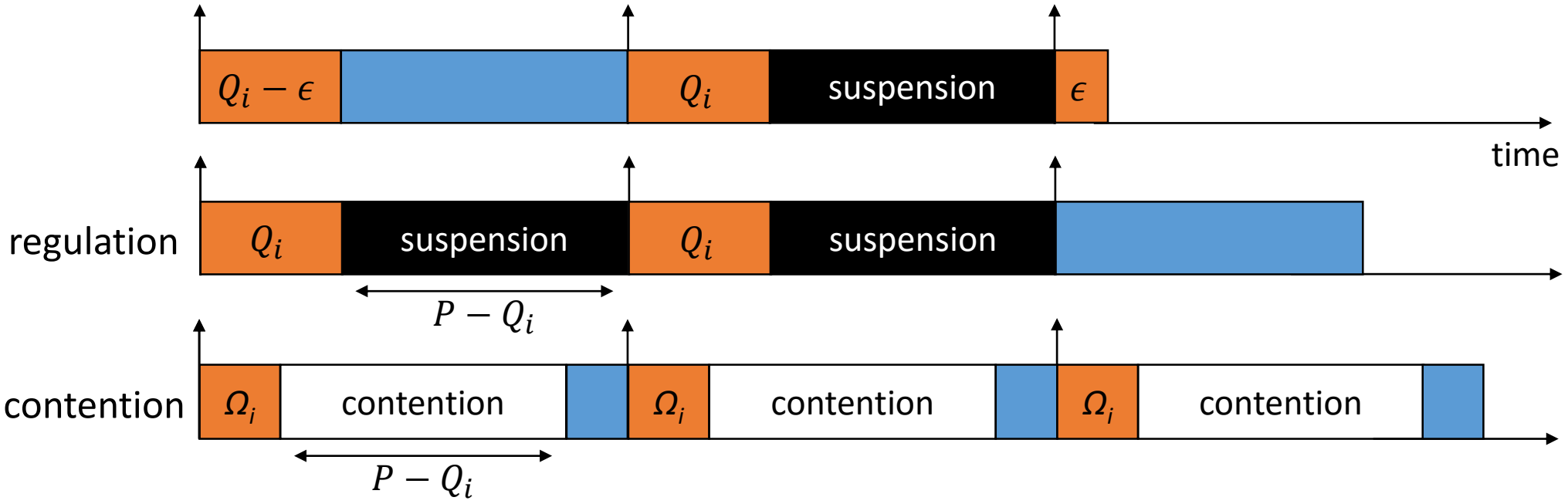

Memory Time Under Regulation

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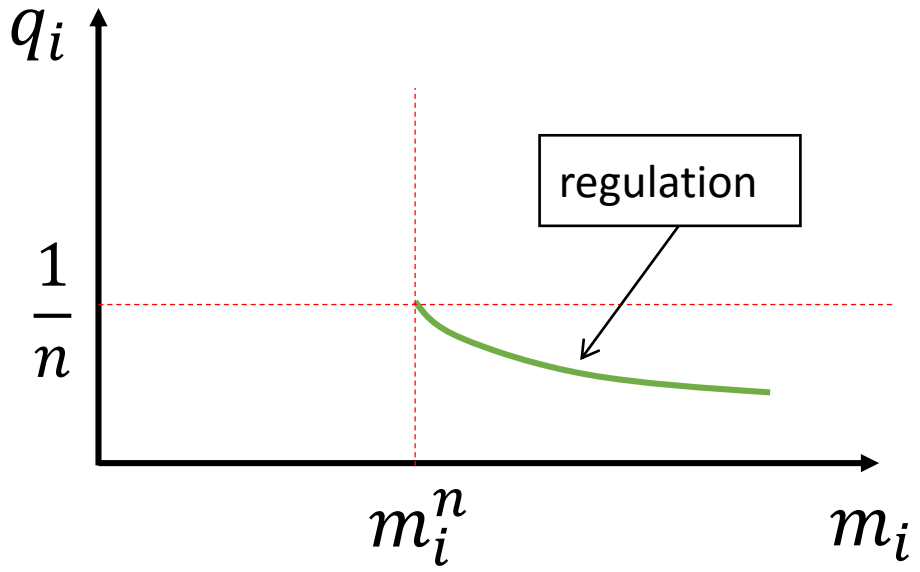

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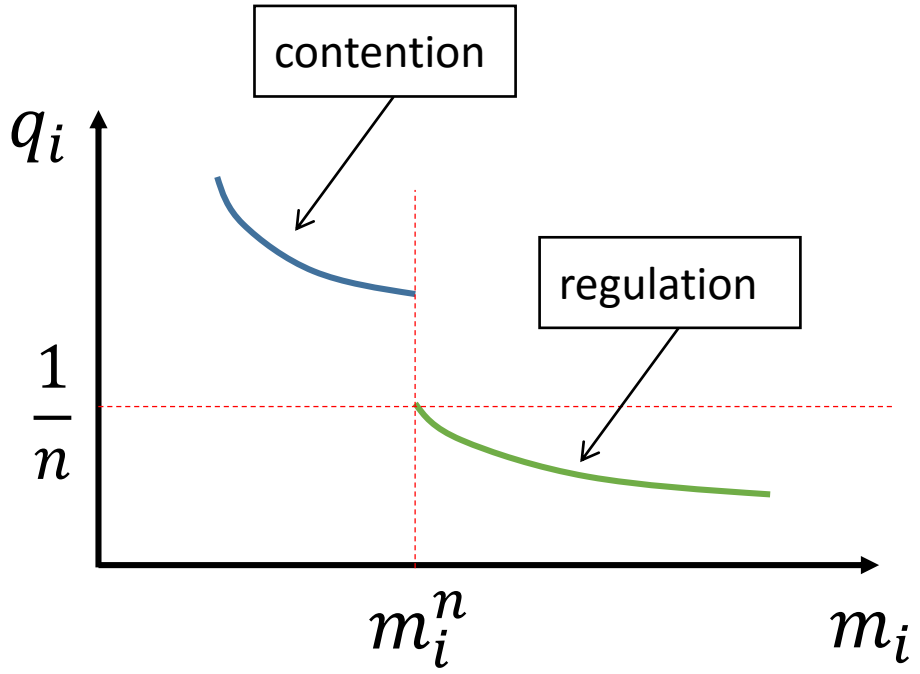
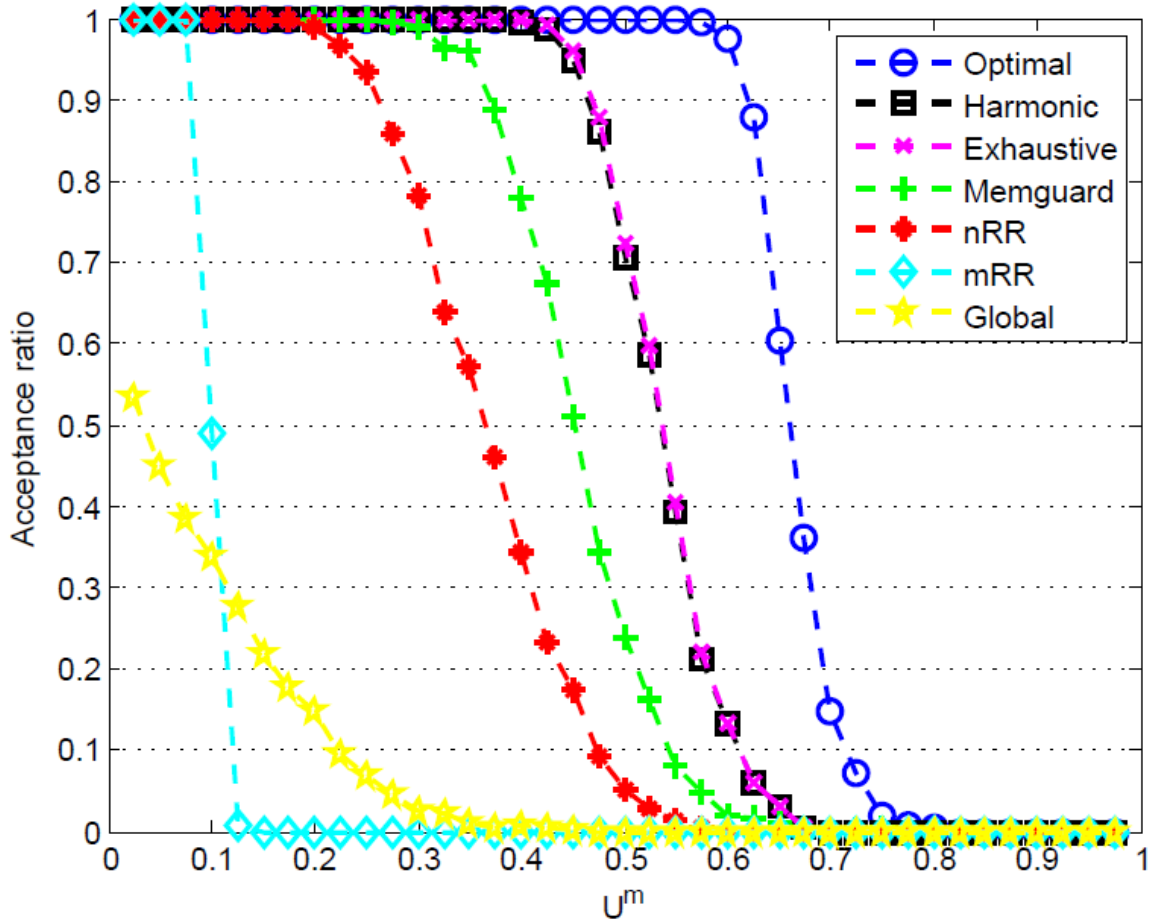


Outline

- Introduction
- Problem Description
- **Our Solution** →
  1. Makespan Bound
  2. Round-robin Arbitration
  3. Trading Cores for Memory Bandwidth
  4. Three Algorithms
  5. **Results**
- Conclusion

$m = 32, n = 5$ and $U^e = 10$



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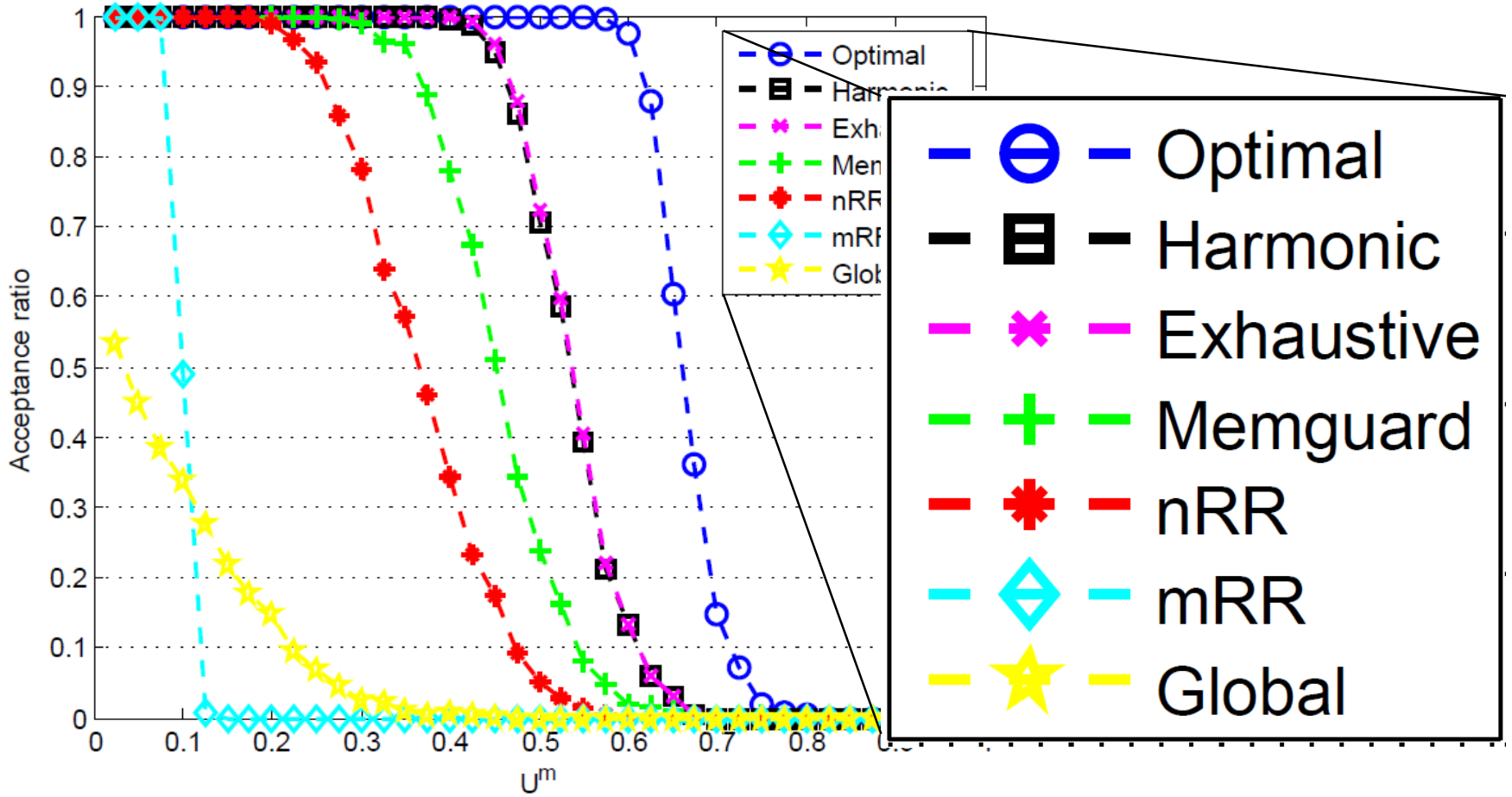

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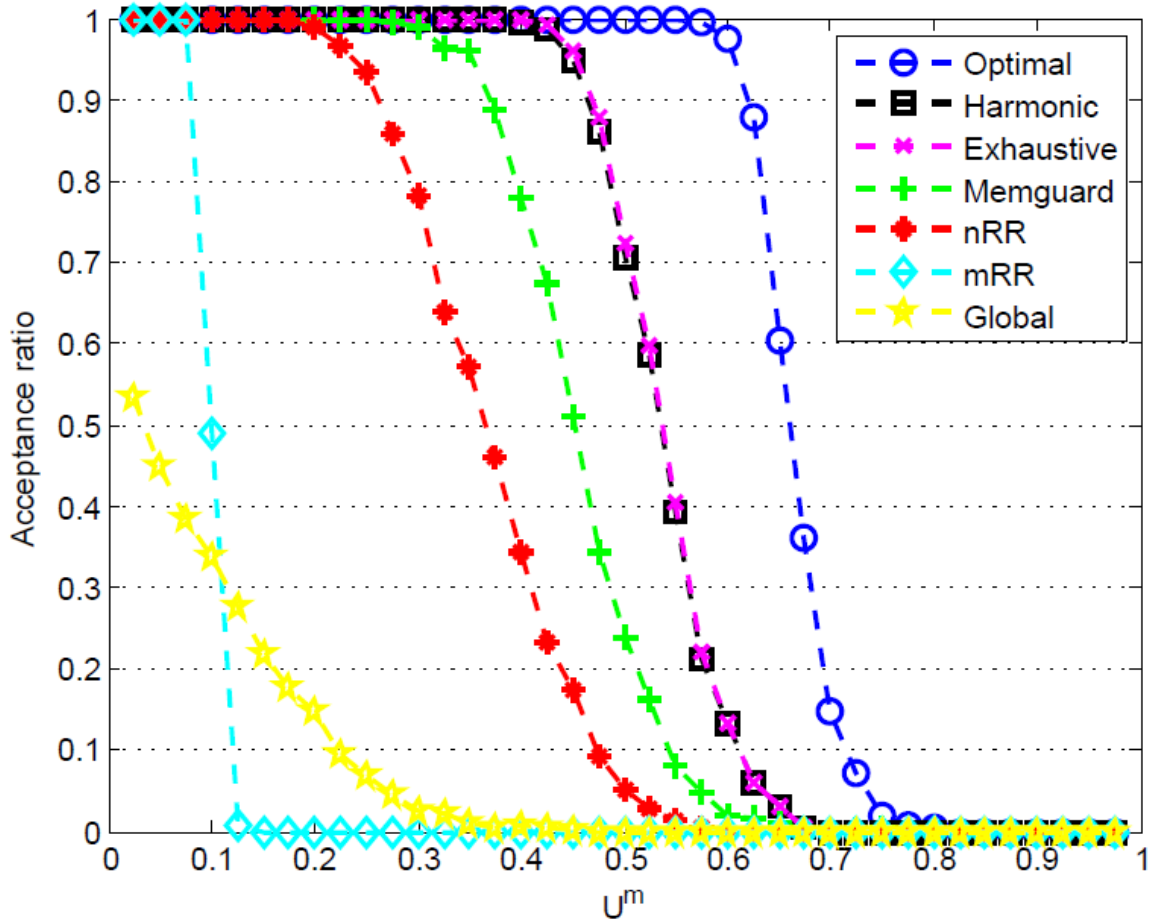

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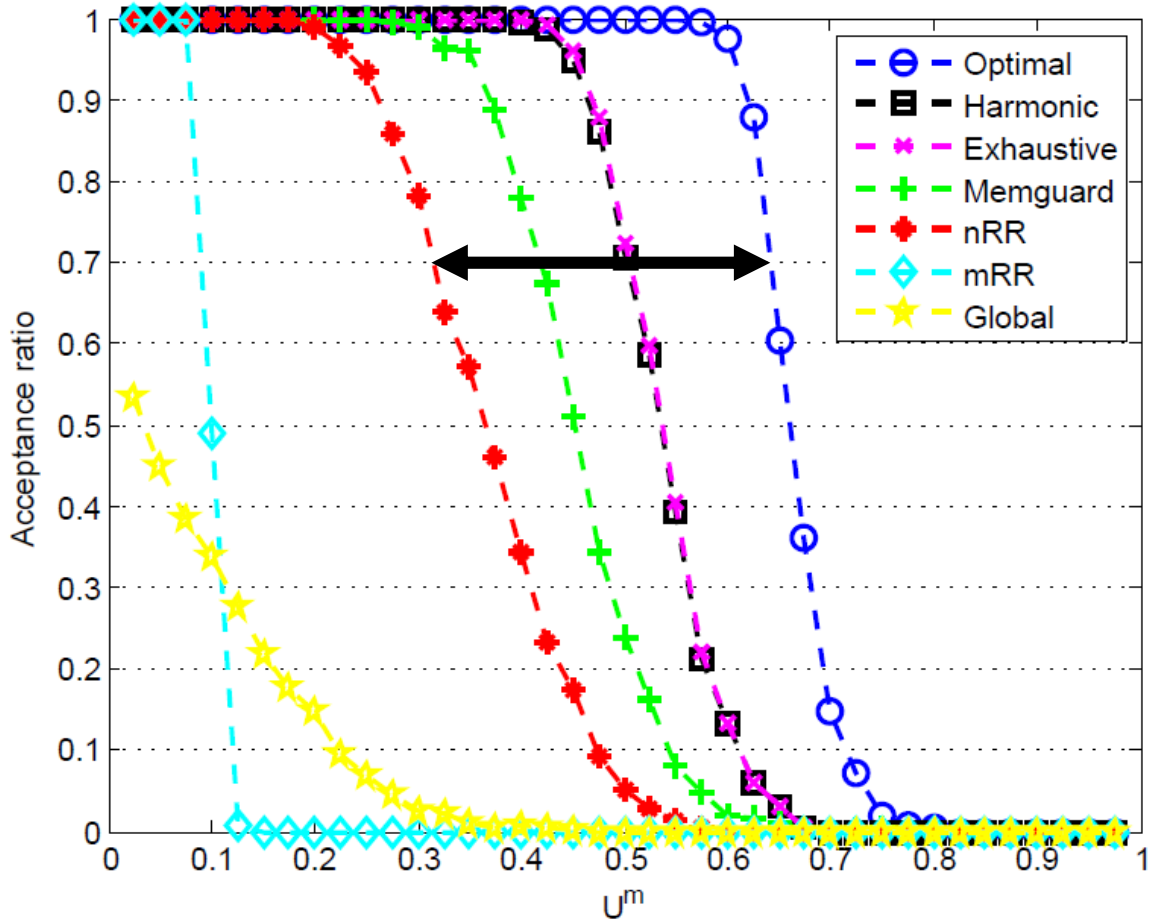

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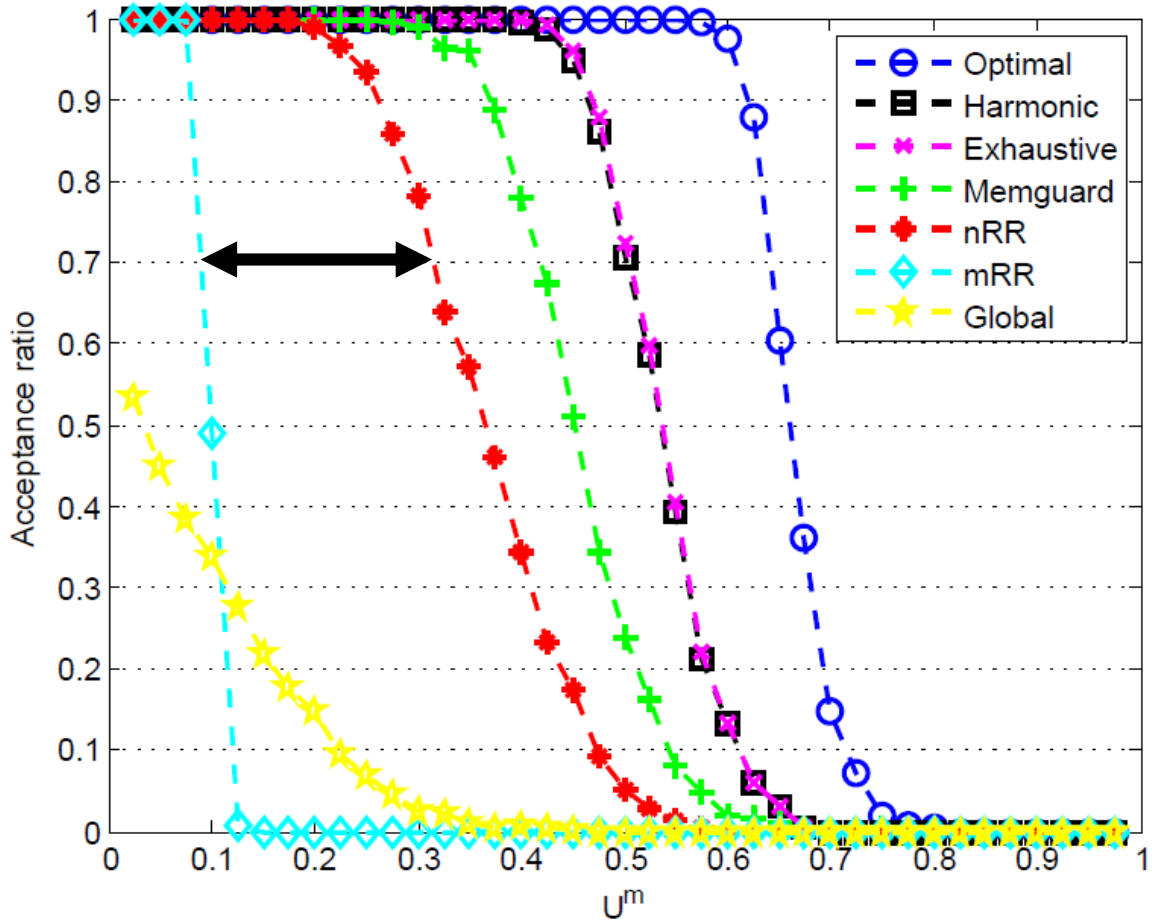

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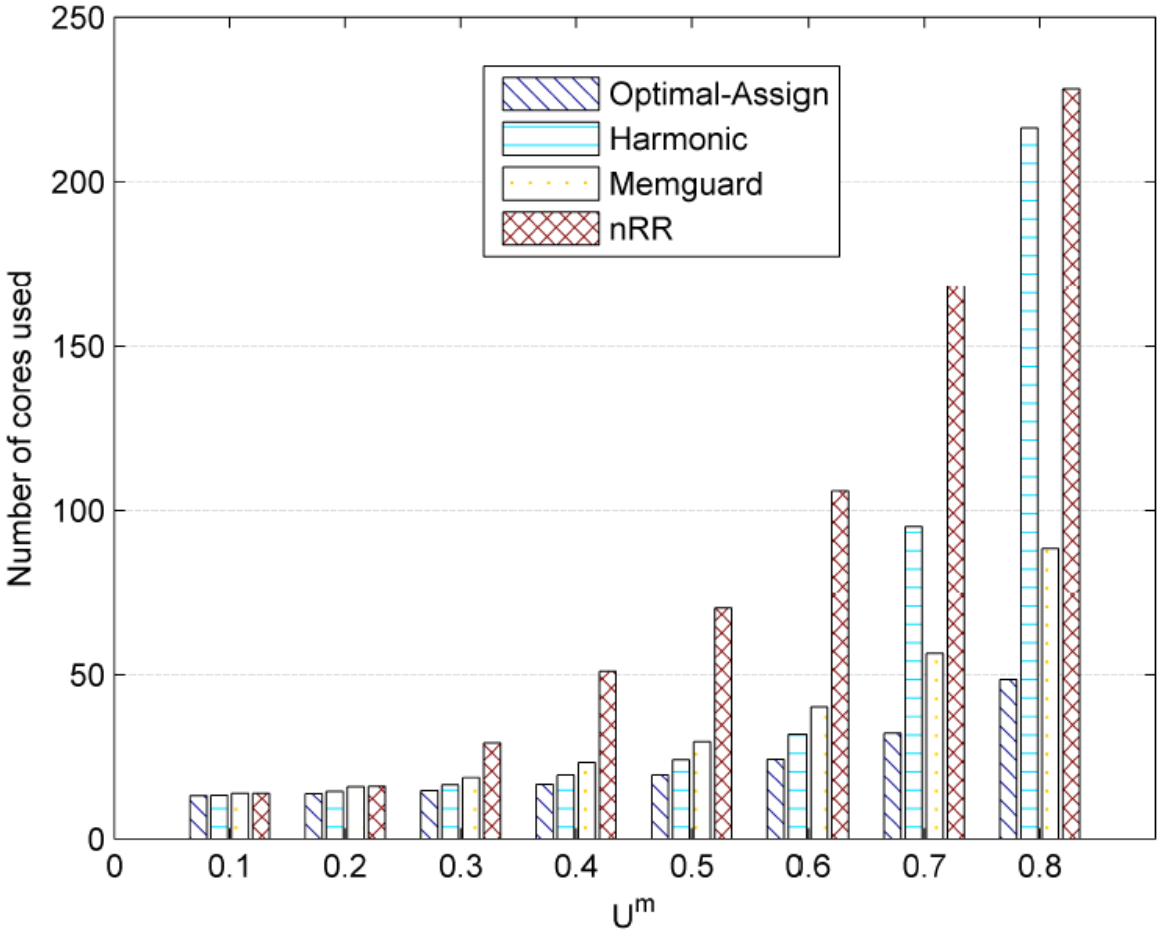

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- The results indicate a significant improvement over nRR